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Worldwide Report

NUCLEAR DEVELOPMENT AND PROLIFERATION

No. 140

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DOCTORS URGE MORE ACTIVE GOVERNMENT ROLE IN NUCLEAR WAR ISSUE

Perth THE WEST AUSTRALIAN in English 1 Mar 82 p 28

[Text]

SYDNEY: Seventy Australian doctors have written to the Prime Minister, Mr Fraser, asking that Australia play a more active role in world disarmament.

The doctors, members of the Australian branch of the Medical Association for the Prevention of War, which was formed six months ago, said that their concern arose from the great risk posed to public health by the threat of nuclear war.

The letter urged Mr Fraser to instruct the Australian delegation to the United Nations General Assembly to call for immediate implementation of a comprehensive programme of international disarmament.

The doctors also said that the Australian Government should exert immediate pressure on the American and Russian governments to suspend further growth of military programmes and stop arms sales to Third World countries.

They called on the Government to establish a fund for peace studies and educational programmes on disarmament.

The association's Australian branch chairman, Dr Richard Kefford, said yesterday that nuclear war was the ultimate public-health issue of our time.

"Public opinion is the only way the imminent health risk of nuclear war can be prevented," he said.

A Third World war was already raging between public opinion and the arms race, he said, and he hoped that public opinion would be victorious as it was in "abolishing the slave trade and bringing a quick end to the Vietnam war."

At the same time, millions of dollars were being diverted from health care to the buying of military equipment.

"On a worldwide basis, 20 times more money was spent on arms than on health," he said.

"In Australia, for a sixtieth of the $300 million paid for HMS Invincible, trachoma could have been eradicated permantly among Aborigines."

At least 40 per cent of the world's people were ignorant of the effects of a nuclear war, he said.

Blast thermal effects and the initial ionising radiation from a one-megaton thermonuclear explosion over a city the size of Sydney or Melbourne would result in the immediate deaths of about 500,000 people.

Australia did not have the medical resources to cope with such a calamity and would be a prime target if war did erupt because of the U.S. military bases, Dr Kefford said.

CSO: 5100/7520

ABORIGINAL OWNERS GIVE GO-AHEAD FOR URANIUM MINING

Agreement Signed

Perth THE WEST AUSTRALIAN in English 2 Mar 82 p 3

[Text] **DARWIN: Traditional Aboriginal owners have given the go-ahead for Australia's biggest uranium development.**

It is Pancontinental's Jabiluka mine in the Northern Territory's Kakadu national park.

The mine will cost an estimated $600 million to construct and uranium and gold production could be worth more than $18,000 million at today's prices.

Negotiating teams from Pancontinental and the Northern Land Council, which represents the traditional owners, initialled terms of agreement in Darwin in the weekend.

The move was announced in Darwin yesterday by the head of the NLC negotiation team, Mr Eric Pratt, QC, of Brisbane.

He said in a statement that the traditional owners at Jabiluka had instructed the negotiating team to initial terms on agreement with Pancontinental last Friday.

The three-man Pancontinental team, led by Mr Terry Cole, QC, of Sydney, travelled to Darwin on Saturday.

Mr Pratt said that comment would now be sought from about 1000 Aborigines who would be affected by the development.

This was required by law.

Mr Pratt said: "It is expected that, with the careful attention paid to the negotiations by the traditional owners and Pancontinental Mining Ltd since the negotiations began a year ago, the terms now agreed will meet early official approval and the way will be open to start construction by the end of the wet season."

In **SYDNEY**, the chairman of Pancontinental, Mr Tony Grey, said he considered the suggestion on the possible start of construction to be "a bit premature."

But he was pleased that the agreement had been initialled.

"It is a major step towards bringing Jabiluka into production," he said.

Mr Grey said that the Federal Government had not allowed Pancontinental to sign sales contracts for uranium before official approval had been given for the mine.

The company would have to sell enough uranium before it could make a start on the mine.

The company was looking at Japan, Europe, the United States and Korea as potential markets, but it was too early to say when enough sales would be made for construction to begin.

Recoverable ore reserves in the Jabiluka 1 and Jabiluka 2 deposits were estimated at 53.3 million tonnes.

However, the company would mine only the Jabiluka 2 deposits.

Tests on the ore indicated that mining would yield 200,000 tonnes of yellowcake and about 12,000kg of gold.

About 1600 people would be employed during the three-year construction phase and about 900 during its projected 25-year operational phase.

Jabiluka Plans

Canberra THE AUSTRALIAN in English 3 Mar 82 p 21

[Text] FULL development go-ahead for the Jabiluka uranium mine in the Northern Territory could still be some time away, a spokesman for the Northern Land Council warned yesterday.

Mr Wesley Lanhupuy, director of the council's bureau, was commenting on Monday's announcement that an agreement which would ultimately allow development of Jabiluka had been initialled.

The agreement was between a professional negotiating team retained by the council and Jabiluka's operator, Pancontinental Mining.

It was hailed as an important step in moving toward development of Jabiluka, and some sources said construction could start as early as this year.

Mr Lanhupuy said that, although he welcomed progress toward completion of the negotiations with Pancontinental, he felt caution should be exercised concerning the time required to finalise these negotiations.

He would not comment on the time required to take the legal steps necessary to get the project under way.

"As stated in the press release from the Northern Land Council negotiating team, the initialled terms of agreement must now go to the Aboriginal people affected by the project for their comment," he said.

"This must occur before a full meeting of the Northern Land Council considers the matter and either consents to the agreement or withholds its consent.

"The Federal Minister for Aboriginal Affairs, Senator Baume, must then give his consent to the agreement before it can be effected."

CSO: 5100/7520

ATOMIC ENERGY COMMISSION WORKS ON SILICON FOR MICROCHIPS

Canberra THE AUSTRALIAN in English 2 Mar 82 p 25

[Text] **A NEW technique for preparing silicon for use in advanced microchips is under consideration at the Australian Atomic Energy Commission at Lucas Heights.**

The technique has already been assessed as a highly attractive commercial step in microchip fabrication.

A senior official of the commission, which performs extensive research in computing, gave details of the new project recently at a special Australia-New Zealand Association for the Advancement of Science (ANZAAS) conference on venture capital and innovation.

The AAEC's commercial applications manager, Mr A. Walker, told the meeting, which presented an almost uniformly bleak picture of the prospects for entrepreneurial high-technology companies in Australia, that researchers at the Lucas Heights Centre had developed several commercial innovations in computing.

"The commission has long been involved in computer usage, and the complex calculations required for nuclear reactors could never be completed within acceptable time limits without sophisticated computer hardware and software," he said.

But the new technique the commission hopes to develop commercially is not an application of computers, but rather a materials science process to provide microchip manufacturers with silicon carefully tailored to specific needs.

Mr Walker told the meeting internal AAEC work in hardware and software had often had direct commercial applications and demonstrated the value of research in high technology.

The best-known innovation in computing developed at Lucas Heights, the AAEC's Pascal compiler, results from nuclear researchers' needs for a versatile programming language.

A project mounted in cooperation with Japanese and American experts had produced the compiler, and subsequent refinements had resulted in "vast improvements".

"The AAEC undertook a market survey and established that ready markets existed for the compiler in Europe and North America," he said.

LICENSED

Agents have been licensed to sell the compiler in both areas, while examination of the Japanese market is under way and a representative is to be appointed in Tokyo this year.

The AAEC has also approved agreements with computer-makers other than IBM — some IBM systems are already compatible with the device — for modification of the compiler to achieve compatbility with their own equipment.

This is expected to increase the market for the compiler and the commission's gain from the project, as the AAEC has reserved the exclusive marketing rights for the modified device.

The marketing of the compiler illustrates the AAEC's pursuit of a Government policy to "maximise the revenue-earning potential of instrumentalities".

The commission is encouraged to develop commercially any processes or techniques perfected in its research which cannot be supplied by the private sector.

One of the most spectacular examples of this category is the new project discussed by Mr Walker at the ANZAAS conference.

"The AAEC is currently investigating the provision of a service which will require considerable innovation and funding," he told the meeting.

The commission planned to use its HIFAR research reactor for treating silicon ingots, as used in the manufacturing of semiconductors.

"To obtain various electrical characteristics of silicon semiconductor material, it is necessary to produce pure silicon crystals and then add — or 'dope' — those crystals with a particular impurity," he explained.

During the early stages of semiconductor development, such impurities had been added to the crystals during the "melt" stage of production.

"Over the past decade the development of high-voltage silicon devices has increased the need for high-resistivity crystals with a dopant uniformity which exceeds the capabilities of conventional production techniques".

For a particular category of silicon crystals (N-type), the technique of thermal neutron irradiation could be used to achieve a high degree of uniformity in doping the silicon with phosphorus.

PROBLEMS

"This technique — termed neutron transmutation doping (NTD) — is the nuclear conversion of silicon atoms into phosphorus dopant atoms by exposing undoped silicon crystals to a suitable flux of thermal neutrons in a nuclear reactor," Mr Walker said.

The technique is highly attractive because it makes possible the production of silicon crystals with extreme homgeneity and resistivity values, for commercial applications.

No problems with radiation are caused by the method under consideration by the AAEC, provided pure silicon is used and is cleaned properly before being placed in the reactor.

"Because of the revenue-earning potential of the process, its knowhow is a carefully guarded commercial secret and very little information is available on the practical means of accomplishing the process," Mr Walker told the meeting.

But he did disclose that AAEC studies had been carried out on the prospects of introducing NTD at Lucas Heights.

The studies have confirmed that the Lucas Heights HIFAR reactor can be used in the commercial process.

The commission plans to carry out trial irradiations of silicon to demonstrate to a potential customer that the method is viable.

But Mr Walker warned that the purchase of the equipment needed to perform the process on a commercial basis would be a "major financial problem" for the AAEC.

CSO: 5100/7520

BRIEFS

URANIUM SITE BAN--Some senior WA unionists hope to ban construction work on the $320 million Yeelirrie uranium project, the developers of which are expected to make the final go-ahead decision by the end of the year. A meeting of union officials in Perth yesterday called for a meeting of construction unions to consider the implementation of the ACTU's policy against the mining, milling and export of uranium. After the meeting the TLC secretary, Mr Peter Cook, said that the meeting was aware of the pressure from governments, the courts and employers on the unions which had attempted to uphold the policy in the Northern Territory and Queensland. There had been physical difficulties in maintaining the bans in the NT and Queensland but there was some hope of more success if the bans were applied before Yeelirrie got off the ground. Much of the meeting was taken up with discussion on the controversial decision of the ACTU executive in December to lift bans on the uranium projects in other States, a move widely interpreted as an end to the policy of opposition to the uranium industry. Despite the ACTU policy there is already a 10-tonne stockpile of yellow cake at Kalgoorlie, the product of testing the Yeelirrie ore at a $20 million treatment plant built on the outskirts of Kalgoorlie. [Text] [Perth THE WEST AUSTRALIAN in English 20 Feb 82 p 7]

NUCLEAR REFERENDUM BAN--The Stirling City Council has been refused permission to spend ratepayers' funds on a referendum on the issue of a nuclear power station in WA. The Cabinet decided yesterday that such a referendum would be improper use of ratepayers' funds. The Deputy Premier, Mr Rushton, said afterwards that under the Local Government Act councils could conduct referendums on matters that came within their jurisdiction. But they must seek the Minister's approval before having a referendum on matters that did not relate to their responsibilities. The council had estimated that the cost of the proposed referendum would be no more than $5000. But the Cabinet had decided to refuse permission for the spending. The Premier, Mr O'Connor, had already made it clear that there was no need for the Government to consider a nuclear power station before the year 2000. On that basis alone, there was no justification for spending ratepayers' funds to arrive at a conclusion that could not influence anything. [Text] [Perth THE WEST AUSTRALIAN in English 23 Feb 82 p 4]

STREET TO ADDRESS UN--The minister for foreign affairs, Mr Street, is to address a major United Nations conference to argue Australia's case for a treaty against the testing of nuclear weapons. Radio Australia's Canberra office says Mr Street will address the United Nations Special Session on Disarmament in June against the background of rising concern in Australia over nuclear weapons. Our office says world leaders scheduled to address the session include President Reagan, the British prime minister, Mrs Thatcher, and Japan's leader, Mr Suzuki. It's also reported that President Brezhnev might attend. The prime minister, Mr Fraser, delivered a major speech at the special session on disarmament 4 years ago. Before and after Mr Fraser's address, Australia has consistently argued at world forums for a treaty against nuclear tests. [Text] [BK120912 Melbourne Overseas Service in English 0830 GMT 12 Apr 82]

CSO: 5100/5645

'HINDU' NOTES KARACHI NUCLEAR EXPERT IN U.S.

Madras THE HINDU in English 22 Mar 82 p 6

[Article by N. Ram]

[Text] WASHINGTON, March 21.

That Mr. Tariq Mustafa, an engineer and experienced official from Pakistan's Atomic Energy Establishment — who had also served with the IAEA — has quietly taken over as the ranking diplomat in charge of technical affairs at the Pakistani Embassy in Washington is a detail that will be of political as well as specialist interest in India.

The U.S. does not have a current nuclear cooperation or supply relationship with Pakistan. Nor for that matter does it have a significant relationship in the science and technology field. The only direct or official U.S. export of sensitive nuclear material to Pakistan during the last four years reportedly involved less than one gramme of plutonium in 1978. However, the procurement of sensitive U.S.-supplied items for Islamabad's clandestine nuclear project via Canada and Europe has been reported and has, in fact, become a minor political scandal in the countries involved.

The connection, if any, of the new Minister (technically in the Pakistani Embassy) with the reprocessing and enrichment projects is not known at this point, and no one has suggested any involvement in the procurement effort. Nevertheless, the decision of the Zia regime to send this nuclear engineer and official connected with the Atomic Energy Commission (PAEC) to Washington, and the U.S. decision to accept a diplomat with this background, might be a sign of the times in the bilateral relationship that seems to have political implications for India.

CSO: 5100/7071

EXPERT CALLS FOR EXPANSION OF NUCLEAR POWER PROGRAM

Bombay THE TIMES OF INDIA in English 23 Mar 82 p 4

[Text] March 22.

The Tarapur Atomic Power Station (TAPS) gives the cheapest nonhydel power in the country, according to Dr. M. R. Srinivasan, director of the power project engineering division of the atomic energy department. The energy cost of the Tarapur power was 18 or 19 paise per kilo watt hour.

In his key-note address on the second national symposium on operating experience of nuclear reactors and power plants at the BARC today, Dr. Srinivasan said the TAPS belied the dismal prophesies made by the cynics when the decision was taken to set up the first nuclear power station. The decision was compared by some critics to a hungry man going to set up a bakery instead of buying a loaf of bread. The record of Tarapur had frustrated the critics, he said.

Despite the political arm twisting with regard to certain essential supplies and the delays, cost escalation and operational problems notwithstanding, time was now ripe for boldly expanding our nuclear power programme, Dr. Srinivasan opined.

The target of 10,000 MW of nuclear power by the turn of the century appeared feasible with our achievements in the engineering and fabrication of critical components, supported by impressive research and industrial infrastructure, he said. However, there should be matching investments in production of heavy water, new uranium mines and other industrial inputs.

Over 530 nuclear units with an aggregate capacity of 400,000 MW were either in operation or under construction all over the world and viewed in proper perspective, their overall benefits to society would far outweigh any possible risks, it was stated.

Analysing the achievements and failures of the power plants, Dr. Srinivasan remarked that our performance standards had to be substantially improved to restore the nation's confidence in our ability to meet the energy needs.

Earlier, Dr. H. N. Sethna, chairman of the Atomic Energy Commission, in his inaugural address, said the adverse effect of voltage and frequency swings was causing serious concern, especially in the case of nuclear power plants and other large thermal units. The concerned authorities should review the present policies and practices to improve the situation, he added.

Though adherence to rigid quality control had delayed the projects, manufacturers should pay greater attention to achieving quality without delays. The service conditions of power generation personnel should be improved adequately, considering their responsibilities and the employment scenario, Dr. Sethna felt.

The three-day symposium is being held under the auspices of the board of research in nuclear sciences of the DAE.

CSO: 5100/7072

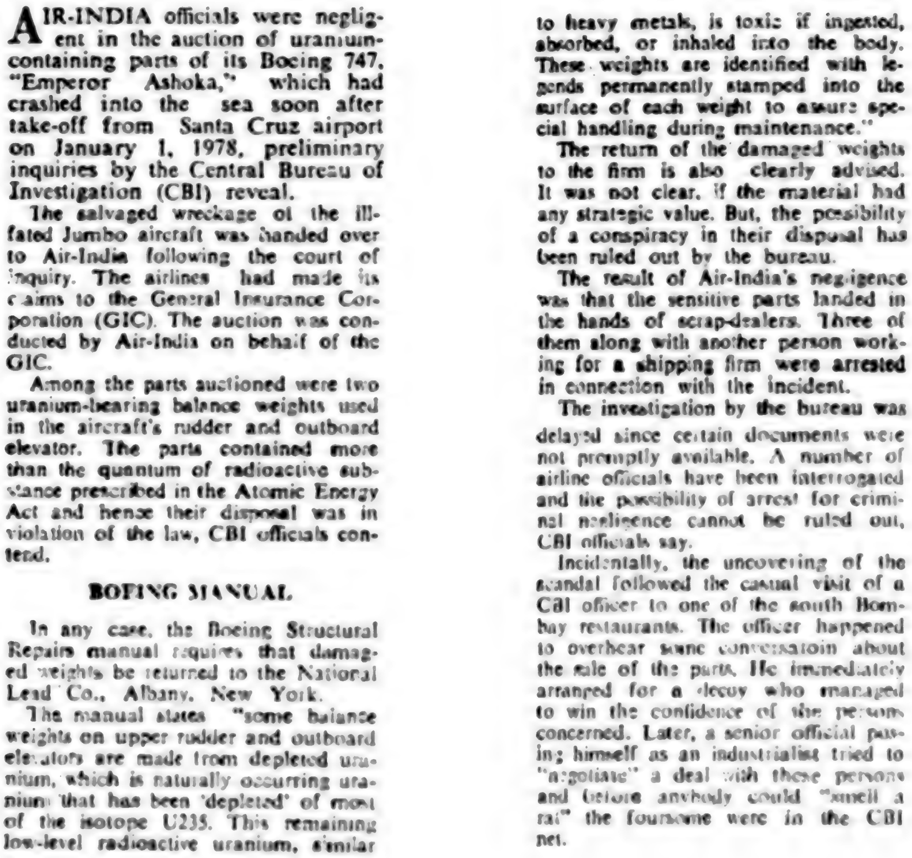
INDIA

AIR INDIA NEGLIGENT IN SELLING RADIOACTIVE PARTS

Bombay THE TIMES OF INDIA in English 21 Mar 82 p 1

[Article by S. Balakrishnan]

[Text]



AIR-INDIA officials were negligent in the auction of uranium-containing parts of its Boeing 747, "Emperor Ashoka," which had crashed into the sea soon after take-off from Santa Cruz airport on January 1, 1978, preliminary inquiries by the Central Bureau of Investigation (CBI) reveal.

The salvaged wreckage of the ill-fated Jumbo aircraft was handed over to Air-India following the court of inquiry. The airlines had made its claims to the General Insurance Corporation (GIC). The auction was conducted by Air-India on behalf of the GIC.

Among the parts auctioned were two uranium-bearing balance weights used in the aircraft's rudder and outboard elevator. The parts contained more than the quantum of radioactive substance prescribed in the Atomic Energy Act and hence their disposal was in violation of the law, CBI officials contend.

BOEING MANUAL

In any case, the Boeing Structural Repairs manual requires that damaged weights be returned to the National Lead Co., Albany, New York.

The manual states "some balance weights on upper rudder and outboard elevators are made from depleted uranium, which is naturally occurring uranium that has been 'depleted' of most of the isotope U235. This remaining low-level radioactive uranium, similar to heavy metals, is toxic if ingested, absorbed, or inhaled into the body. These weights are identified with legends permanently stamped into the surface of each weight to assure special handling during maintenance."

The return of the damaged weights to the firm is also clearly advised. It was not clear, if the material had any strategic value. But, the possibility of a conspiracy in their disposal has been ruled out by the bureau.

The result of Air-India's negligence was that the sensitive parts landed in the hands of scrap-dealers. Three of them along with another person working for a shipping firm were arrested in connection with the incident.

The investigation by the bureau was delayed since certain documents were not promptly available. A number of airline officials have been interrogated and the possibility of arrest for criminal negligence cannot be ruled out, CBI officials say.

Incidentally, the uncovering of the scandal followed the casual visit of a CBI officer to one of the south Bombay restaurants. The officer happened to overhear some conversatoin about the sale of the parts. He immediately arranged for a decoy who managed to win the confidence of the persons concerned. Later, a senior official passing himself as an industrialist tried to "negotiate" a deal with these persons and before anybody could "smell a rat" the foursome were in the CBI net.

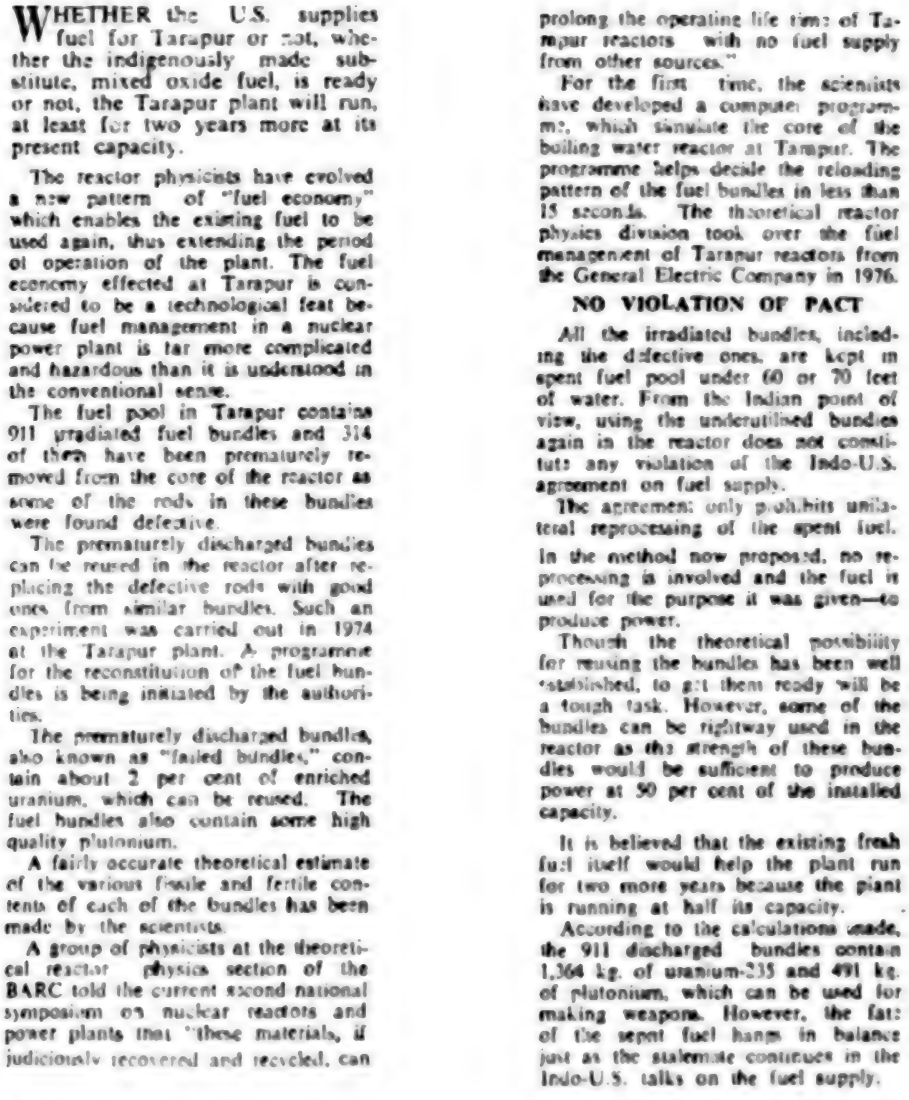
CSO: 5100/7070

FUEL ECONOMY PLAN FOR TARAPUR DESCRIBED

Bombay THE TIMES OF INDIA in English 25 Mar 82 p 1

[Article by S. Kumar]

[Text]



WHETHER the U.S. supplies fuel for Tarapur or not, whether the indigenously made substitute, mixed oxide fuel, is ready or not, the Tarapur plant will run, at least for two years more at its present capacity.

The reactor physicists have evolved a new pattern of "fuel economy" which enables the existing fuel to be used again, thus extending the period of operation of the plant. The fuel economy effected at Tarapur is considered to be a technological feat because fuel management in a nuclear power plant is far more complicated and hazardous than it is understood in the conventional sense.

The fuel pool in Tarapur contains 911 irradiated fuel bundles and 314 of them have been prematurely removed from the core of the reactor as some of the rods in these bundles were found defective.

The prematurely discharged bundles can be reused in the reactor after replacing the defective rods with good ones from similar bundles. Such an experiment was carried out in 1974 at the Tarapur plant. A programme for the reconstitution of the fuel bundles is being initiated by the authorities.

The prematurely discharged bundles, also known as "failed bundles," contain about 2 per cent of enriched uranium, which can be reused. The fuel bundles also contain some high quality plutonium.

A fairly occurate theoretical estimate of the various fissile and fertile contents of each of the bundles has been made by the scientists.

A group of physicists at the theoretical reactor physics section of the BARC told the current second national symposium on nuclear reactors and power plants that "these materials, if judiciously recovered and recycled, can prolong the operating life time of Tarapur reactors with no fuel supply from other sources."

For the first time, the scientists have developed a computer programme, which simulate the core of the boiling water reactor at Tarapur. The programme helps decide the reloading pattern of the fuel bundles in less than 15 seconds. The theoretical reactor physics division took over the fuel management of Tarapur reactors from the General Electric Company in 1976.

NO VIOLATION OF PACT

All the irradiated bundles, including the defective ones, are kept in spent fuel pool under 60 or 70 feet of water. From the Indian point of view, using the underutilised bundles again in the reactor does not constitute any violation of the Indo-U.S. agreement on fuel supply.

The agreement only prohibits unilateral reprocessing of the spent fuel.

In the method now proposed, no reprocessing is involved and the fuel is used for the purpose it was given—to produce power.

Though the theoretical possibility for reusing the bundles has been well established, to get them ready will be a tough task. However, some of the bundles can be rightway used in the reactor as the strength of these bundles would be sufficient to produce power at 50 per cent of the installed capacity.

It is believed that the existing fresh fuel itself would help the plant run for two more years because the plant is running at half its capacity.

According to the calculations made, the 911 discharged bundles contain 1,364 kg. of uranium-235 and 491 kg. of plutonium, which can be used for making weapons. However, the fate of the sepnt fuel hangs in balance just as the stalemate continues in the Indo-U.S. talks on the fuel supply.

CSO: 5100/7073

PLANS FOR CHASHMA NUCLEAR COMPLEX REVIVED

BK140646 Hong Kong AFP in English 0631 GMT 14 Apr 82

[Text] Islamabad, 14 Apr (AFP) -- Pakistan is to go ahead with a nuclear power project at Chashma, with a generating capacity of 937 megawatts, almost 50 percent more than plannned in an earlier project, official sources said today.

The project, costing over 1,600 million dollars, will be completed by mid 1988, they said. Chashma is some 250 kms (160 miles) south of here.

An original project, planned under executed former Premier Zulfiqar Ali Bhutto in 1976, called for a 600-megawatt nuclear complex including a fuel reprocessing plant from France.

The plan was abandoned owing to stiff opposition from the United States, which feared Pakistan might acquire the ability to detonate an atomic bomb. Former French President Valery Giscard d'Estaing suspended the deal despite Pakistan's assurances that its nuclear program was geared at peaceful purposes.

No details were given about the new set up, but official sources stressed that nuclear generation was vital owing to an acute shortage of power. With the high cost of oil, nuclear power was the only economical alternative for Pakistan, the sources said.

Pakistan has a first nuclear power plant in Karachi, the country's largest city.

CSO: 5100/2144

PEOPLE'S REPUBLIC OF CHINA

'WEN WEI PO' ON PRC NUCLEAR, SPACE TECHNOLOGY

HK090548 Hong Kong WEN WEI PO in Chinese 9 Apr 82 p 1

[Dispatch from correspondent Cheng Hsiang [4453 5046]: "China's First Nuclear Powerplant To Be Built in Shanghai in 2 Years"]

[Text] According to an authoritative person in Beijing's science circles, China will score successes of great significance in advanced branches of science in the next 1 or 2 years.

China is going to apply nuclear technology to the civil industries in the next 1 or 2 years, said this authoritative person at a news conference held here today. The first nuclear powerplant in the country will be built in Shanghai. This nuclear powerplant, to have a capacity of generating 300 billion watts, will be a pressurized water-type reactor. At present, all the design work has been completed.

This authoritative person said that in view of the technological level in the world today, only a nuclear powerplant with a designed generating capacity of 900 billion watts is commercially feasible. Even so, it must be recognized that this project will mark tremendous progress for China. China has decided to first build a small experimental nuclear powerplant. Then, from the experience gained, it can improve on design work, and thus speed up the application of nuclear technology to civil industries.

As reported, this nuclear powerplant project has been designed and most of the equipment and accessories required, except two essential component parts, will be made by China itself. The production of these two component parts, namely, the steam generator and the major pump, is still beyond China's capability. Therefore, it is believed that China will have to import them from foreign countries.

This authoritative person also disclosed that China would launched a synchronous satellite in 1983 or 1984. This project, if successful, will push China's space technology a great step forward.

As he explained, in order to launch a satellite which moves at the same speed as that of the earth's rotation so that it can permanently stay at a relatively fixed point above the earth, two technical problems have to be overcome. First, the satellite must be kept under control at all times, and second, rocket thrust must be powerful enough to inject the satellite into orbit. China's performance in solving the first problem has already been outstanding. After the United States and the Soviet Union, China is the third country in the world to have successfully retrieved a satellite. This shows that China has reached a certain level in satellite control techniques. In the future, China will improve its techniques by launching a synchronous satellite. The second problem will be a test for China's ability or rocket propulsion as a synchronous satellite needs to be injected into a higher orbit. At present, China possesses two-stage rockets. To inject a satellite into a higher orbit requires a three-stage rocket and, moreover, the use of liquid propellent. This is really a severe test. Now, China is conducting research in this field. If this research is successful, China's space technology will be pushed up to a higher level.

This authoritative person said that the transition from theory to practice marks a leap, and the course from experiment to commercial product marks another leap. Actually China is not weak in terms of basic theory, but relatively weak in the fields of experimentation and application. Therefore, based on the outcome of the above two projects, we will be able to estimate in general the level of science and technology of China in the 1980's.

CSO: 5100/2144

PEOPLE'S REPUBLIC OF CHINA

'KYODO' CITES FANG YI ON PRC NUCLEAR RESEARCH

OW070043 Tokyo KYODO in English 0008 GMT 7 Apr 82

[Text] Beijing, April 7, (KYODO) -- Chinese Vice Premier Fang Yi said Tuesday that China is trying to make a small particle accelerator on its own. He thus indicated that China was engaged in the development of such an accelerator for use in nuclear tests and other purposes.

Fang revealed this in a meeting with Tetsuo Kondo, chairman of the Japanese House of Representatives Science and Technology Committee, who is currently visiting Beijing. He did not disclose details on the matter, saying only that the accelerator being developed is "small." Observers believe, however, that China is engaged in the development of a proton synchrotron.

During the meeting Fang also told Kondo that China will continue to carry out its energy policy with emphasis laid on water power and coal and explained it does not plan to lay stress on nuclear power generation.

CSO: 5100/2144

SOUTH KOREA

BRIEFS

SECOND POWERPLANT TO OPEN--Seoul, April 10 (YONHAP)--South Korea's second atomic power plant with a capacity of 678,000 kilowatts will begin operations by the end of the year, government sources said Saturday. The plant, equipped with Canadian-made nuclear reactors, is being built at the industrial town of Wolsong in southeastern Korea at cost of about 928.5 million U.S. dollars. Construction began in October 1977. South Korea's first nuclear plant at Kori on the southeast coast is now in operation with a capacity of 590,000 kilowatts. The nuclear industry is a priority in the South Korean Government's plan to develop substitute sources of energy. [Text] [SK100840 Seoul YONHAP in English 0741 GMT 10 Apr 82]

CSO: 5100/2144

ARGENTINA

CNEA OFFICIAL, SOVIET COMMENT ON URANIUM DEAL

PY071902 Buenos Aires TELAM in Spanish 1808 GMT 6 Apr 82

[Text] Buenos Aires, 6 Apr (TELAM) -- An important contract for the supply of 100 kg of 20 percent enriched uranium was signed today between the National Atomic Energy Commission [CNEA] and the autonomous self-financed Soviet foreign trade company, Tekhsnabeksport.

The document was signed by CNEA Chairman Vice Adm Carlos Castro Madero and by Viktor Ivanovich Zharikov, deputy general director of the Soviet company Tekhsnabeksport, in the presence of Soviet Ambassador Sergey Striganov, high-ranking Foreign Ministry officials and members of the Soviet Embassy in Buenos Aires.

Castro Madero stated that this contract involves a development of nuclear relations with the Soviet Union, and it is the first step toward more important ones, which will allow Argentine development in the nuclear field.

Zharikov, in turn, admitted the importance of this contract, not so much because of the volume, but because it can open the path which may increasingly strengthen relations at this level between the two countries.

Finally, asked about the current conflict between our country and Great Britain, Soviet Ambassador Striganov limited himself to saying that he would rather speak at this moment about the nuclear contracts.

Questioned further, he stated that the Soviet Union abstained from voting against Argentina because it believes that sovereignty over the Malvinas Islands must be discussed at the United Nations because of its colonialist characteristics. I hope that everything will be solved peacefully, he added.

CSO: 5100/2144

ARGENTINA

USSR TO SUPPLY ENRICHED URANIUM TO ARGENTINE

OW071248 Beijing XINHUA in English 1236 GMT 7 Apr 82

[Text] Buenos Aires, April 6 (XINHUA) -- The Soviet Union is expected to replace the United States as a supplier of enriched uranium for Argentina, according to three agreements on nuclear raw materials signed by the Soviet Union and Argentina here today. Under these agreements, the Soviet Union will provide Argentina with heavy water and 100 kilograms of enriched uranium in return for four tons of the latter's concentrate uranium ore. The Soviet enriched uranium will be used in two nuclear reactors in Argentina while the heavy water will be used to make up for the losses of the nuclear power station in Atucha in its daily operation.

Argentina reportedly got enriched uranium from the United States in the past. However, the United States stopped its supply because Argentina refused to sign the nuclear non-proliferation treaty.

Trade between Argentina and the Soviet Union has grown rapidly in recent years. In 1981, 75 percent of Argentina's exported grain went to the Soviet Union. Argentina also had 3.418 billion dollars of favorable balance of trade between the two countries last year. During the first quarter this year, the Soviet Union bought 7 million tons of Argentine grain, 2.5 million tons more than that specified by agreement. It is estimated that the Soviet Union will buy 20 million tons of grain from Argentina this year while seeking to export chemical products, electric generators, turbines and heavy water to that country.

CSO: 5100/2144

DEVELOPMENT OF NUCLEAR INDUSTRY URGED

Jiddah ARAB NEWS in English 11 Mar 82 p 1

[Text]

DOHA, March 10 (AFP) — Arab countries should coordinate their efforts to develop a pan-Arab electro-nuclear industry which would be under their full control at every stage, several delegates told the second Arab energy conference here Wednesday.

The Vice Secretary General of the Organization of Arab Petroleum Exporting Countries (OAPEC) Adnan Mustafa has stressed that Arab countries cannot obtain nuclear fuel from elsewhere in the world for political reasons.

The development of an Arab electro-nuclear industry will depend on uranium reserves in Arab countries, he said. The Arab world has proven uranium reserves of 60,000 tons in Algeria, Egypt, Morocco, and Somalia.

Two Kuwaiti scientists, Adnan Chinab-Eldin and Yousif Rashid, stressed that the Arab world is trailing in the nuclear field. With the exception of Egypt, Iraq and Algeria, and "perhaps" of Libya, nuclear technology was "virtually absent from Arab countries", they said.

They added that while the Arab world was experiencing "relative prosperity" in the energy sector, it was necessary to develop a nuclear industry to prepare for the years when the oil was exhausted.

They noted that unless a country became totally aligned on the United States, politically, commercially and militarily, it was virtually impossible to acquire American nuclear reactors.

The attitude of Europe was "more objective" as was shown by an agreement between France and Iraq, they said. They suggested that "the power of oil in negotiations" should be used to obtain nuclear technology for peaceful purposes.

During a subsequent debate, an American, Richard Wilson, who is a professor at Harvard University, suggested that industrialized countries' radioactive waste could be buried in he desert in Egypt or Saudi Arabia in return for technology such as port installations.

But this provoked a strong reaction from Arab delegates. One delegate retorted: "Why not choose the Nevada Desert?"

Gebeily, a prominent nuclear authority in Egypt, said the Egyptian government recently turned down a proposal by Austria to dispose of its nuclear waste in the Egyptian desert on both sides of the Nile.

CSO: 5100/4715

EGYPT

BRIEFS

NUCLEAR AGREEMENT--The Consultative Council met today under the chairmanship of Council Speaker Dr Subhi 'Abd al-Hakim and approved the agreement signed between Egypt and the International Atomic Energy Agency [IAEA] on the application of the guarantees connected with the treaty for the nonproliferation of nuclear weapons. The agreement stipulates that the IAEA take every precaution to safeguard commercial and industrial secrets as well as other prohibited information reaching it. [Excerpt] [NC121547 Cairo Domestic Service in Arabic 1500 GMT 12 Apr 82]

CSO: 5100/2144

BRIEFS

NUCLEAR POWER STATIONS--The heads of the nuclear engineering department at the Technion yesterday said in Haifa that in their view it is feasible to extablish nuclear power plants in Israel even without Israel signing the international convention against the proliferation of nuclear arms. At a press conference conducted in anticipation of a conference of the nuclear societies in Israel, which is to take place next week at the Technion, the spokespersons--professors Amos Nota, Naphtali Shafrir and Yitzhaq Segal--said that in their opinion a good portion of what is required to set up a nuclear power plant will come from domestic development and manufacture, and additional elements may be acquired at various places throughout the world. The spokespersons called upon the government to formulate policy and to prepare a multi-year plan on this matter, including the administration of a project to explore the ways to set up the first nuclear power plant in Israel. Heretofore, they said, the government of Israel has not formulated policy in the area of nuclear energy. However, there is no doubt that it is inevitable, since, sooner or later, Israel will have to build a nuclear power plant. The professors noted that the Technion is prepared to train personnel for the planning and construction of power plants. [By Tzvi Tal, Correspondent in Haifa] [Tel Aviv YEDI'OT AHARONOT in Hebrew 11 Feb 82 p 4] [Text] 8090

CSO: 5100/4709

BRIEFS

URANIUM PROSPECTS FOR 1990's--Niger could become fourth in the league table or uranium producers in the world, overtaking Namibia by 1990, according to a recent announcement at the UN in New York. The United States is the world's largest producer, followed by Canada, South Africa, Namibia, Niger and France. Niger overtook France in 1979. The London-based Uranium Institute agreed that Niger would be well placed to take and hold the number four position if the price holds up. Production in 1980 is estimated at 4,100 tonnes and provisional figures for 1981 showed an increase to 4,400 tonnes. The bulk of the increased production, which would take Niger to about 10,000 tonnes by 1993, would come on stream when, analysts predict, demand for uranium will improve. World stocks are very high at the moment, partly because of the oil glut which has discouraged demand for the metal. But by the early 1990s it is expected that demand for electricity and the price of oil will have increased sufficiently for demand for uranium to increase. [Text] [London WEST AFRICA in English No 3374, 5 Apr 82, p 955]

CSO: 5100/5642

BRIEFS

URANIUM MINING TREATY PLANNED--Bulawayo.--A treaty between Zimbabwe and Mozambique on the exchange of information on mining and border exploration of minerals such as uranium, is being considered. Zimbabwe's Secretary for Mines, Mr Christopher Ushewokunze, hopes to establish an umbrella agreement on mining with the Mozambicans. This is just one of the future trends in mining for Zimbabwe, according to Mining and Engineering, which interviewed the Minister after his recent trip to Mozambique with the Prime Minister, Mr Robert Mugabe. Mr Ushewokunze said mineral deposits extending across the borders of the two countries would be more easily mined if the governments co-operated.--Sapa. [Text] [Johannesburg THE CITIZEN in English 13 Apr 82 p 13]

CSO: 5100/5643

DENMARK

BRIEFS

PRO-NUCLEAR COMMITTEE FORMED--The introduction of nuclear power as soon as possible is important in order for Denmark to retain its competitive power and its welfare. This statement was made by the newly formed "Committee for the Introduction of Nuclear Power in Denmark," which has just sent out a cassette tape with Professor of Reactor Physics, P. L. Ølgård. Behind the committee are Erik Tillisch, Lord of the Bedchamber, Rosenfeldt, Bernt Johan Collet, squire and M.P., Lundbygaard, Knud Olesen, merchant, Th. Olesen, Inc., J. Sønderholm, the Commercial Bank, David Gress, author, Stege, Thorvald Kortbæk, director, Copenhagen, Jens Chr. Rotbøll, president of association, and Eigil Osted, director. Bernt Johan Collet tells BERLINGSKE TIDENDE that the committee is neither a competitor of Danatom nor of REO but a supplement. "We feel that it is possible to provide information on nuclear power in an objective and proper way," the squire says with reference to the cassette tape just sent out. On the committee, he says that it is composed of some people who intend to spend part of their spare time on the work for nuclear power and who consider the economic aspects to be so important that they are willing to work for it. "Cheap energy is not only important for our competitive power but for our welfare and has a direct effect on the economy of the individual citizen," says Bernt Johan Collet, who, moreover, considers the problems of pollution caused by coal-firing to be so serious as to demonstrate the advantage of nuclear power. [Text] [Copenhagen BERLINGSKE TIDENDE in Danish 1 Apr 82 p 6]
7262

CSO: 5100/2130

FRANCE

EXPERIMENTS WITH CARAMEL FUEL IN OSIRIS REACTOR DESCRIBED

Paris REVUE GENERALE NUCLEAIRE in French No 6 Nov-Dec 81 pp 567-576

[Article by Jean-Marie Cerles, Chief of Osiris reactor operations, CEA; and Ghislain de Contenson, engineer in the Technology Department, CEA]

[Text] After a presentation of the Caramel fuel to be used in the Osiris reactor, the authors describe the first experimental phases of the use of this fuel in the reactor. They then analyze the behavior of the fuel and its consequences for operational purposes.

Starting in the 1960s and until the present time, the many research reactors all over the world have used highly enriched fuel. The choice of this type of fuel, which offers some technical advantages, was made possible because the United States made the necessary fuel available. The technical advantages of this fuel are quite obvious: the very low amount of highly enriched uranium required can be placed in a low density matrix. In the present case, a uranium and aluminum alloy is used to produce fuel elements consisting of thin plates. These fuel elements are perfectly suited for producing the high specific powers associated with the high neutron flows needed for these reactors.

This dissemination of large amounts of highly enriched uranium led to a growing awareness of the associated dangers of proliferation, and during the 1970s, a movement developed, tending to restrict the supply of highly enriched uranium. Then there arose the problem of converting the highly enriched fuel used in research reactors into a slightly enriched fuel, with the upper limit for enrichment set at 20 percent U 235.

While research and development programs for the production and qualification of fuels that could be used for slightly enriched fuels were being set up in a number of countries, such as the United States, Germany, and France (CERCA [Company for the Study and Manufacture of Atomic Fuel]), in 1977 the CEA [Atomic Energy Commission] decided to conduct an experiment using slightly enriched fuel with the Osiris reactor at Saclay. The technology for such an experiment, developed at the CEA, was already available. This fuel, known by its generic name of Caramel, consists of uranium oxide strips, whose thickness can vary, encased in zircaloy and assembled to form plates. By using this fuel, the problem of increasing the density of the uranium matrix necessary for the reduction of enrichment was resolved: 9 g U/cm^3, compared with 1.6 g U/cm^3 in the U-Al alloy.

The Osiris reactor has been using this new fuel for nearly 2 years now (it began in January 1980). This experiment has provided a very complete and strict test; its duration has now been long enough to produce meaningful results in the following areas: operating conditions, consequences for testing, behavior and monitoring of the fuel.

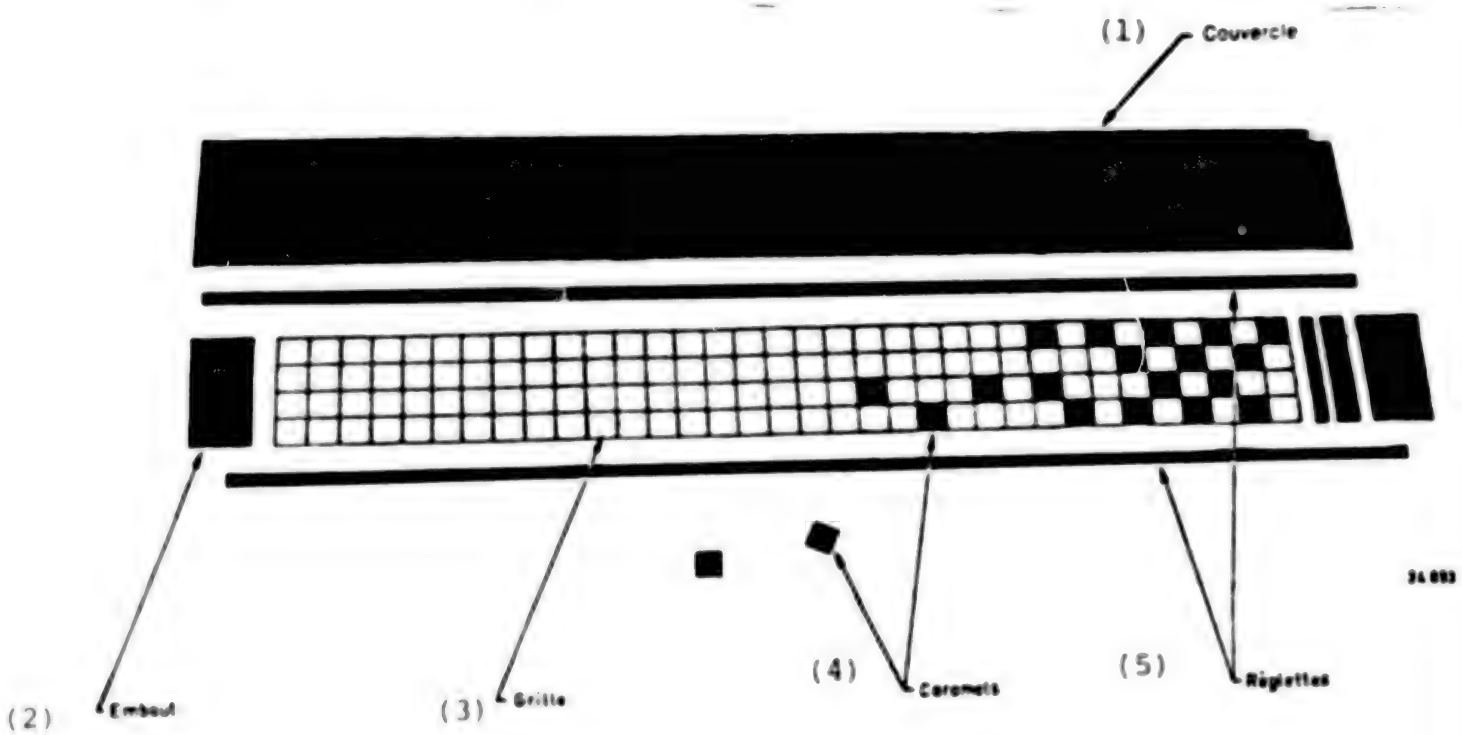


Figure 1: Elements of a Caramel plate.

Key for Figure 1:

1. Lid
2. Tip
3. Grid
4. Caramels
5. Side strips

I The Caramel Fuel

1.1. Presentation

One result of the various programs conducted in France for the design, manufacture, and development of nuclear fuels has been the CEA's development of a uranium oxide fuel (called the Caramel fuel) whose characteristics and performance are essentially quite different from those of the conventional rod or pencil type of fuel. The Caramel fuel is distinguished from the conventional type of nuclear fuel by the following features:

a. Its plane geometry;

b. The lack of any free volume;

c. Good contact between the oxide and the protective shield (absence of any clearance);

d. The splitting of the fuel into a large number of compartments, all tightly sealed in relation to each other.

The basic element of the Caramel fuel is in the shape of a plate, formed by two zircaloy sheets which act as lids. Between these sheets are the strips of UO_2, which are themselves arranged in the cavities of a grid. The plane geometry is an effective way to convert the disadvantage of the poor conductivity of uranium oxide into an advantage, by combining a high specific power with a low fuel temperature.

Because of their use in water-cooled reactors, the components of the Caramel fuel--the UO_2 and the zircaloy--are very well known in terms of their physical properties, their behavior under irradiation, their manufacture, etc.

The special features of the Caramel fuel do require particular operating conditions. Because of the lack of free volume (except for the open porosity of the fuel), the temperature at which fission gases begin to be released must never be exceeded. For this reason, it is essential to have excellent contact between the oxide and its covering from the very start; this contact should last for the entire life of the fuel element. The manufacturing methods described later can ensure the good quality of this contact.

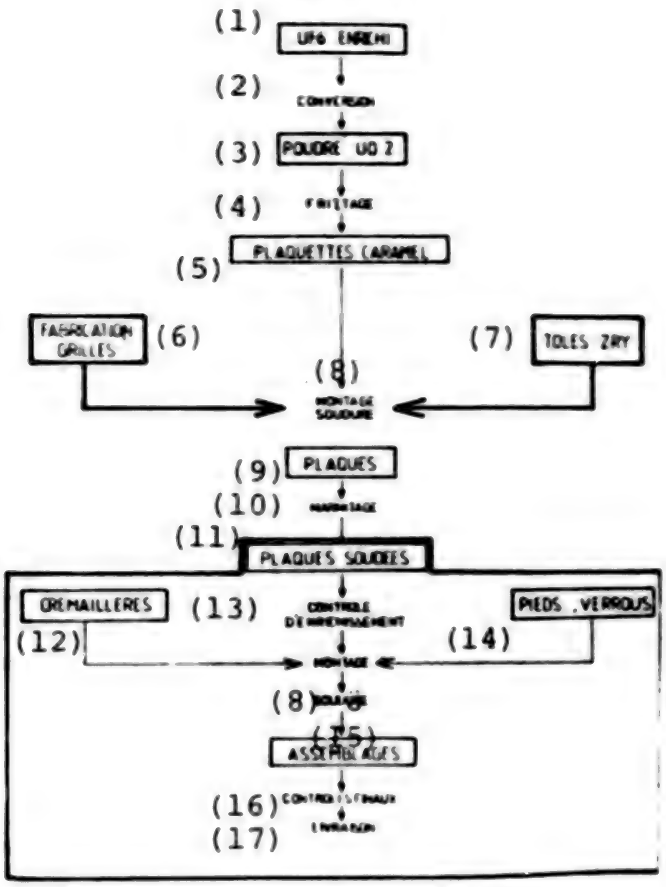


Figure 2: Manufacturing schematic for the Caramel fuel.

Key:

1. Enriched UF_6
2. Conversion

3. UO_2 powder
4. Pressing
5. Caramel strips
6. Manufacture of grids
7. Zircaloy sheets
8. Assembly/soldering
9. Plates
10. "Shelling" [form of soldering]
11. Soldered plates
12. Racks
13. Enrichment control
14. Feet, bolts
15. Assemblies
16. Final controls
17. Delivery

The splitting of the fuel into a large number of tight compartments is a major safety factor. Because of its dispersion, any possible loss of seal only puts a small amount of fissile material in contact with the coolant, which limits any possible contamination of the primary circuit.

The operating temperature, well below the temperature at which fission gases begin to be released, is another safety factor.

The first studies done at the CEA were oriented toward such applications as electricity or heat-generating reactors and naval propulsion reactors, and these used very thick Caramel (4 mm), because the specific powers required were limited. The thin Caramel, which was developed later, has been used in the Osiris research reactor, for which very high specific powers are needed (the average value is approximately 1,640 W/cm^3, and the maximum value is 4,300 W/cm^3).

Table 1 lists the main features of the reactors which are operational or planned (such as the Thermos reactor) with Caramel plate fuels.

1.2. Description of the Osiris Fuel

The basic module of the Osiris fuel element of the Caramel type is a plate 700 mm long, 80 mm wide, and 2.25 mm thick. Figure 1 lists its various components. The UO_2 fuel is pressed into a parallelopiped with a square section of 17.1 x 17.1 mm and 1.45 mm thick. These strips are arranged in the cavities of a grid and encased between two sheets of zircaloy. This unit, fitted with side and end pieces made of zircaloy, undergoes a series of soldering procedures in order to ensure the perfect seal of each UO_2 strip in relation to the outside and in relation to its nearby strips. These manufacturing procedures are described later.

Réacteur (1)	Puissance (MW) (2)	Epaisseur CARAMEL (mm) (3)	(4) Température gaine (°C)	Pression réfrigérant (bars) (5)	(6) Puissance spécifique moyenne (W/cm³)	(7) Puissance spécifique maximale (W/cm³)
Pile piscine (OSIRIS) (8)	70	1,45	140	3	1 640	4 300
Calogène (THERMOS) (9)	100	2,25	160	11	275	1 070
ISIS	0,7	1,45	95	1,5	16	43

Table 1: Principal Features of Operational or Planned Reactors Using Caramel Fuel

Key:

1. Reactor
2. Power (MW)
3. Caramel thickness (in mm)
4. Temperature of casing (°C)
5. Coolant pressure (bars)
6. Average specific power (W/cm^3)
7. Maximum specific power (W/cm^3)
8. Swimming pool reactor (Osiris)
9. Heat-generating reactor (Thermos)

Clusters are formed of 14 or 17 parallel plates, which are kept joined by slotted side pieces. They are fitted with a base or foot to provide a water supply, and a head for handling.

Table 2 lists the main features of an Osiris fuel element. These features are shown in comparison with those of a highly enriched uranium fuel element, whose structures are made of aluminum.

The essential differences consist of:

a. The metallurgical nature of the fuel: UO_2 instead of U-Al alloy;

b. The nature of the enclosure and structures: zircaloy instead of aluminum;

c. The thickness of the plates: 2.25 mm instead of 1.27 mm;

d. The total amount of uranium, which is considerably increased.

Type d'élément combustible (1)	(2) Nombre de plaques	Epaisseur d'une plaque (3) (mm)	Epaisseur du canal d'eau (4) (mm)	Charge en uranium (5) (kg)	Charge en U 235 (6) (kg)
Elément à uranium très enrichi U-Al (7)					
Elément standard (8)	24	1,27	2,1	0,420	0,390
Elément de commande (9)	20	1,27	2,1	0,282	0,262
Elément CARAMEL (10)					
Elément standard	17	2,25	2,6	8,6	(7 %) 0,602
Elément de commande	14	2,25	2,8	5,3	0,371

Table 2: Comparison of Highly Enriched Uranium Fuel Element and Caramel Fuel Element for the Osiris Reactor

Key:

1. Type of fuel element
2. Number of plates
3. Thickness of plate (mm)
4. Thickness of water supply ducts (mm)
5. Amount of uranium (kg)
6. Amount of U 235 (kg)
7. Highly enriched uranium U-Al element
8. Standard element
9. Control element
10. Caramel element

The amount of fissile uranium (U 235) also had to be increased in order to compensate for absorptions caused by the U 238.

1.3. Manufacturing and Quality Control

1.3.1. Manufacture of Strips

The manufacturing of the Caramel fuel is done in facilities belonging to the CEA or to its subsidiaries. Some components, such as the zircaloy sheets, and cast or machined parts, are provided by industry. The manufacturing schematic is given in Figure 2.

The following manufacturing phases can be distinguished.

Production of oxide strips (Caramel). The oxide strips are made by pressing UO_2 powder, using moisture. The process used is called the DCN (Double Normal Cycle). The pressing is done under hydrogen, at a temperature close to 1,600°C. The density of the pressed Caramel is equal to 94 percent of the theoretical density.

We should mention that the production of Caramel fuels benefits from the experience acquired in this field with PWR [Pressurized Water Reactors] fuels.

Deposit of Antidiffusion Barrier

Each Caramel is covered with a layer of chrome, deposited by cathode pulverization. This chrome acts as a barrier, preventing the diffusion of oxygen in the zircaloy, which could take place during the process of soldering by diffusion, which is also called "shelling," and is described later.

1.3.2. Manufacture of Plates

The following elements are combined to form a plate (Figure 1):

a. oxide strips;

b. zircaloy grid, made by soldering zircaloy wires;

c. a nickel tip, which has an effect on the neutrons;

d. side pieces made of zircaloy;

e. end pieces, also made of zircaloy; and

f. zircaloy sheets used as enclosures.

The Caramel are placed in the grid cavities. The entire unit--the grid with its Caramel fuel, the side pieces, the end pieces, and the tip--is placed between two sheets of zircaloy, and soldered to form a tight seal. The plate closing procedures are done in the following order:

a. After resistance soldering of the various parts, the sides are soldered to the roller, using a resistance solderer;

b. The end pieces are then soldered by electron bombardment, which also places the unit in a vacuum;

c. After the plate is closed in this way, it is transferred to a diffusion soldering enclosure, where it undergoes a high temperature ($\sim$800°C) and high pressure ($\simeq$1,000 bars) treatment for 4 hours; this procedure is also called "shelling." This process ensures that all the zircaloy components, especially the grids and sheets, are properly soldered, separating each strip of UO_2 and ensuring a good contact between the oxide and the enclosure sheet.

d. This shelling process is then followed by a control procedure, done in a vacuum at 700°C.

1.3.3. Quality Control

All the materials and components must meet the stringent specifications: specific control procedures have been established, and a quality control organization has been set up.

These controls are done at all phases of production, and cover in particular:

a. Measurement of components and assembly (measurement of ducts);

b. Enrichment of each fuel strip;

c. The quality of soldering between metal parts;

d. The quality of the contact between the oxide and the enclosure.

These controls are done during the manufacturing process in the following manner.

1.3.3.1. Controls during the Production of Basic Elements

UO_2 strips: measurement (length, width, thickness, density, appearance, control of chrome deposit).

The tolerable surface density defects have been defined on the basis of correlations between the dimensions of the defect and the residual thickness of the sheet after diffusion soldering.

Zircaloy parts: measurement. Surface condition after abrasion.

1.3.3.2. Controls of finished plates

a. appearance;

b. measurement;

c. control of absence of entrapped gases, by thermal treatment at 700°C in a vacuum, with the plates free;

d. control of quality of soldering by micrography and corrosion testing;

e. enrichment controls.

The enrichment control of the Caramel plates consists of determining the surface content of U 235 by neutron measurement. This control offers a number of advantages:

a. overall control of the various manufacturing tolerances of the Caramel elements;

    1. enrichment;

    2. uranium titer in the UO_2;

    3. density of the pressed UO_2;

    4. thickness of the Caramel;

b. possibility of a systematic control of all the strips which combine to make up a fuel element;

c. speed of control in relation to conventional methods;

d. exact measurement of the combined manufacturing variances;

e. control of a characteristic (surface content of U 235) that can be used directly to calculate the reactor's performances; and

f. control of the quality of the oxide-enclosure contact.

The quality of the oxide-enclosure contact appears to be an important parameter in the design of the Caramel fuel. A method of thermal analysis by infrared thermovision has been developed.

(1) NUMERO PLAQUE : OS 2645 S T

(2) CHARGE NOMINALE : 90.5 MG ^{235}U/CM^2 (E = 7.00 %)
(3) CHARGE MOY.MESUREE : 91.8 MG ^{235}U/CM^2 (+ - 0.5)
(4) ECART CORRESPONDANT : 1.4 %

ECART % (5) ^{2}	A 100	B 200	C 300	D 400
1	0.4	1.0	1.4	1.1
2	1.9	1.0	0.8	2.8
3	1.9	- 0.1	1.9	0.5
4	- 0.3	- 0.2	1.0	1.4
5	1.9	1.2	2.0	1.3
6	3.0	0.7	0.6	1.5
7	1.6	1.2	1.6	3.3
8	1.1	2.4	1.6	1.2
9	2.7	2.2	1.1	1.5
10	0.9	2.0	- 0.0	1.1
11	2.4	0.0	0.6	1.6
12	2.1	1.4	2.2	1.2
13	2.7	0.9	1.3	0.6
14	2.1	0.7	1.1	1.2
15	1.3	1.3	2.0	- 0.2
16	1.3	1.6	2.1	2.5
17	2.5	2.1	2.3	1.6
18	2.4	0.7	2.6	1.4
19	2.5	1.1	1.7	2.0
20	0.6	1.1	0.8	0.5
21	1.2	0.7	2.1	1.5
22	2.1	1.2	0.9	2.1
23	2.4	1.5	2.6	1.8
24	0.4	1.5	1.1	0.7
25	2.2	1.7	0.4	2.1
26	1.5	1.7	1.3	1.3
27	2.9	1.6	0.9	2.7
28	2.4	0.8	0.7	1.8
29	1.0	1.0	1.1	1.5
30	- 0.1	0.9	1.5	1.6
31	1.2	2.6	- 0.2	0.1
32	1.3	1.7	1.2	0.8
33	2.1	1.3	0.9	1.0
34	2.5	- 0.1	2.0	2.4

ECART (6) MIN - 0.3 (7) MAX 3.3 % (8) CHARGE NOMINALE
CHARGE ^{235}U/CM^2 PLAQUE HOMOGENE (9)

Figure 3: Caramel plates: Example of control of content of U 235/cm^2.

Key:

1. Plate number: OS 2645 S T
2. Nominal content
3. Average content measured
4. Corresponding variation
5. Percentage of variation
6. Minimum variation
7. Maximum variation
8. Nominal content
9. 235 U/cm^2 content; homogenous plate

However, this method is not being used now, for the test done at 700°C in a vacuum can be used to test the plates under conditions which are more stringent than the conditions of operation in a pool reactor. Until the present, this test has been found to be highly satisfactory.

1.3.3.3. Control during the final assembly

a. overall measurement of the assembly (by placement in a standard measurement gauge);

b. measurement of all ducts;

c. control of superficial pollution.

The controls and final acceptance are handled by an organization independent of the fuel manufacturer. Moreover, a system of quality assurance has been set up and works with studies, development, and testing.

A descriptive file is drawn up for each fuel assembly. These records contain all the data for the assembly:

a. data concerning the various componenets: source, method of production, mechanical characteristics, measurements and weight, chemical analyses;

b. measurement results for each plate;

c. observations after a visual examination of each plate;

d. results of the enrichment control, done for each strip;

e. results of the measurement of all water ducts (a recording is made for each row of strips).

Figure 3 gives some examples of the data compiled for each fuel assembly, and contained in this descriptive file.

1.3.4. Manufacturing Experience

The experience acquired during manufacturing is based on the development of a large number of assemblies, in addition to the production of units for experimental irradiations. Table 3 gives a summary of this experience.

(1) Réacteur	(2) Nombre d'assemblages	(3) Nombre de plaques	(4) Nombre de plaquettes UO_2	(5) Poids UO_2 (kg)
(6) PAT (*)	16	576	101 952	1 497
(7) CAP (**)	4	44	13 728	182
OSIRIS	> 200	3 400	462 400	2 019

Table 3: Assemblies produced

1. Reactor
2. Number of assemblies
3. Number of plates
4. Number of UO_2 strips
5. UO_2 weight (kg)
6. Ground Prototype: PWR type reactor used as a prototype for naval propulsion, located at Cadarache.
7. Advanced Boiler Prototype: PWR type reactor with a power of 100 thermal MW, also located at Cadarache.

At present, the production capacity is 200 assemblies of the Osiris type a year.

1.4. Qualification of the Caramel Fuel

1.4.1. Various Qualification Programs for the Caramel Fuel

A broad testing and qualification program for the Caramel fuel has been undertaken and executed within a broad range of specific powers and combustion ratios. Its purpose was to determine first of all the technological limits, then the safe and reliable areas of operation of this type of fuel. This program includes both parametric tests in irradiation test circuits in test models with a limited number of Caramel elements, and irradiations of experimental assemblies done in the Osiris reactor and in the CAP and CAT prototype reactors.

Following are the major outlines of this program, as well as the principal results that have been obtained.

1.4.1.1. The EL 3 Program

A first exploratory program designed to determine the technological limits of the fuel was begun at Saclay in the EL 3 reactor between 1965 and 1970. It worked with 17 irradiation test units (including five or nine Caramel each) which were irradiated with variable combustion ratios and specific powers.

The range of specific power explored extends from 1,000 to 3,000 W/cm^3. The enclosure temperature: 280°C to 340°C. The results of these tests showed that:

a. It is possible to achieve combustion ratios of 30,000 MWj/t with specific powers as high as 3,000 W/cm^3 without damaging the fuel. Beyond 30,000 MWj/t, if this specific power is maintained, there is a danger of causing the strips to swell, thus releasing gases. This would not necessarily cause the enclosures to break.

b. On the other hand, if the specific power is decreased at this stage of irradiation, it is possible to reach combustion ratios up to 50,000 MWj/t without any notable change in the structure of the UO_2 strips.

1.4.1.2. Siloe Program

Two irradiations without external pressure were conducted in the swimming pool reactor, Siloe, at Grenoble, using two small units with a few test models each.

The irradiation conditions were as follows:

Specific power	1,060 W/cm^3		1,500 W/cm^3
Duration	245 days	and	202 days
Combustion ratio	18,300 MWj/t		25,100 MWj/t
Temperature	100°C		100°C

The results obtained show a very good behavior of the assemblies in the reactor and a very good appearance after irradiation.

1.4.1.3. Program of Experimental Irradiations in the Osiris Reactor

These are still experimental irradiations of test units, each with several Caramel, and should not be confused with the irradiations of Osiris elements done in actual size. The irradiations were done in an NaK container at a temperature of 300°C with external pressurization of 140 bars.

Historically, two series of irradiations were done:

a. In 1973-1974, with Caramel thicknesses of 3 and 4 mm;

b. In 1975-1978, with just a thickness of 4 mm; the objective was to determine the technological operating limits.

The test units in the first series exceeded 40,000 MWj/t with a thickness of 3 mm and 37,500 MWj/t with a thickness of 4 mm. The examinations conducted revealed the absence of any release of gases and the very good behavior of the separators.

The results cover in particular:

a. The thermal conductance of the uranium oxide as a function of the combustion ratio;

b. The determination of the extreme limit for the normal operational temperature ;

c. The extreme temperature of the separators;

d. The operating limits for the two thicknesses of 3 and 4 mm during operation.

Figure 4 gives an example of the operational limit for a Caramel 4 mm thick up to a mass combustion of 50,000 MWj/t U. If we know the extreme temperature for the fuel operation, it is possible to transpose these results to other Caramel configurations. So, in the case of the Osiris reactor, the extreme specific powers would be above 5,000 W/cm^3.

Other test irradiations were done in a loop on the Osiris reactor. Two irradiations were done as part of the Irene program, using a pressurized water loop which reproduced the real coolant conditions. One of them caused a leak detection signal due to the instrumentation (passage of thermocouples). This was used for safety studies (Ir-06). The second concerned the study of deposits of corrosion products. Moreover, power cycling tests were done, still using the 4 mm-thick Caramel, before the shutdown of the Osiris reactor in July 1978, on test models which reached a combustion ratio of 30,000 MWj/t. These cyclings were done under the following conditions:

a. high level	1,250 W/cm^3
b. low level	375 W/cm^3
c. speed of rise and descent	400 $W.cm^{-3}/mm^{-1}$
d. number of cycles	3,634

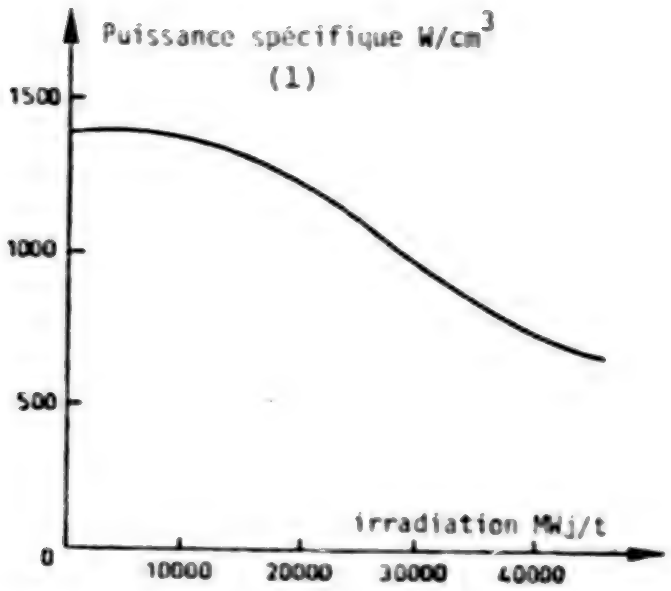


Figure 4: Operational limit for a Caramel 4 mm thick

Key:
1. Specific power W/cm^3

1.4.2. Carine Experiment: Study of Fuel Shield Rupture in Osiris

In order to evaluate the safety in operation of such a fuel in relation to the risks of a release of fission products or fissile matter in the primary circuit of the slightly pressurized reactor, a test of a shield rupture was done under conditions representative of the Osiris operation. This test was conducted in the independent test loop of the EL 3 reactor. This loop, located in the heavy water tank, is a heavy water cooling circuit distinct from the reactor's circuit. Thus, any possible pollution of heavy water is limited to this circuit.

1.4.2.1. Test Conditions

The fuel element, which was produced according to the same process as the standard fuel element, contained 32 strips of UO_2 enriched to 7 percent. The shield defect was a circular hole with a surface of approximately 1 mm^2. The specific power during irradiation was raised to 3,050 W/cm^3. Cooling was provided by the circulation of heavy water at a flow rate of 10 m/s. These conditions are quite similar to those in Osiris.

The fuel plate was placed in an aluminum case channeling the water to both sides of the fuel plate in order to provide adequate cooling.

The power released in the fuel was obtained by thermal records. The rise in the cooling water temperature was measured by a triple probe placed at the intake of the assembly in the reactor and by three triple thermocouples placed at the outlet. The flow rate was measured by a meter placed on the circuit.

Detection of the shield rupture was done by two parallel systems. One used a BF 3 counter which was normally in use on the loop, while the other was equipped with a ^{3}He counter similar to the one installed in Osiris.

1.4.2.2. Test Results

Changes in the DND (Delayed Neutron Detection) signal as a function of time are shown in Figure 5. We notice the presence of three pseudo-plateaus corresponding to increasing levels of activity. Their duration is about 5 hours for the first, 30 hours for the second, and 3 hours for the third. During the duration of the first two pseudo-plateaus, there were bursts of activity reaching peaks whose amplitude was close to the average signal.

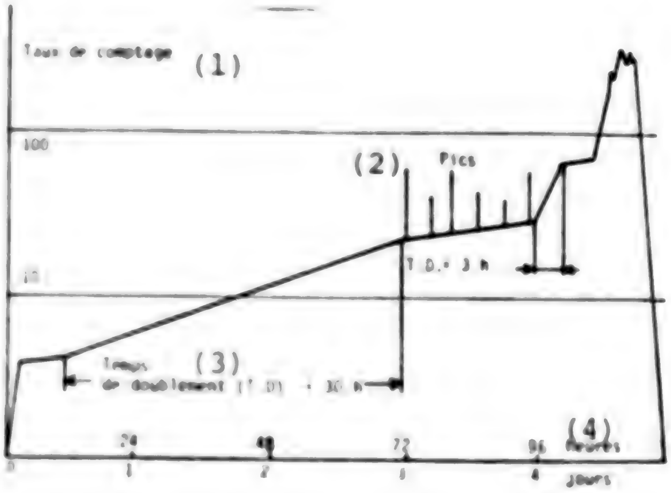


Figure 5: Changes in the Counting Rate of Neutrons Delayed during Irradiation

Key for Figure 5:

1. Counting rate
2. Peaks
3. Doubling time
4. Hours/days

Then there was an abrupt signal acceleration following an exponential curve.

The time required for the signal to double--30 hours during the first phase--was only 3 hours during the second phase.

After the third pseudo-plateau, there were recorded peaks of activity, with the average signal first changing rapidly and then stabilizing for 1 hour 40 minutes.

The delayed neutron detection equipment used was representative of the device installed in the Osiris reactor, which permits a determination of the time necessary for reaching the detection threshold of a shield rupture. The results indicate that the detection threshold is exceeded after the third pseudo-plateau.

Despite the continuation of irradiation in these conditions for about 2 hours, we found a very low level of radionucleid activity indicating a fuel leak. Moreover, the examinations made of the test fuel element after irradiation showed an absence of any significant change in the opening initially made and in the underlying fuel.

This test therefore showed the excellent behavior of the Caramel fuel in the event of a shield rupture, and also the possibility of detecting such a rupture in Osiris before any significant contamination of the reactor circuits could occur.

1.4.3. Irradiation of Three Complete Fuel Elements in Osiris

Before the start of service of the Osiris core, three precursor elements were irradiated in the old core. These irradiations were done during the first 6 months of 1978.

The first element put in the reactor was removed during the shutdown of the reactor for maintenance in July 1978, at an average irradiation level of about 18,000 MWj/t U. A destructive examination of this element was made at the Irradiated Fuels Research Laboratory at Saclay before the fueling of Osiris.

The other two elements were put in the reactor during the core fueling with Caramel fuel, for durations of one and two cycles, respectively, in order to actually have precursors, up to an average irradiation level of 18,000 to 20,000 MWj/t U.

II Changing the Fuel in Osiris

2.1. Refueling Schedule

The decision to conduct an operational experiment using slightly enriched fuel in Osiris was made in early 1977. The fuel chosen was the only one that would be available in the near future, the Caramel fuel. For the requirements of this operation, the thickness of the strips was reduced to 1.45 mm, as we said earlier.

The operation itself, with its main features: studies, work on the reactor, fuel testing, experimental studies, safety studies and reports, fueling and tests, took place following this schedule:

a. General studies, development of the fuel: 1977;

b. Testing of fuel elements in Osiris: early 1978;

c. Work on the Osiris reactor for the Caramel transformation: from autumn 1978 to the summer of 1979;

d. Isis safety report: January 1978;

e. Fueling of Isis and start of experimental studies on the core: October 1978;

f. Thermal studies on the loop in Grenoble: second half of 1978 to early 1979;

g. Osiris safety report: November 1978;

h, Fueling of the Osiris core: September 1979;

i. Tests of power increase: December 1979 to February 1980.

Note: The reactor was stopped at the end of July 1978 for the usual summer shutdown and for some major work, involving repairs of linings of the reactor (ducts, deactivation tanks), combined with work required for the change of fuel.

2.2. Adaptation of the Facility

The Osiris reactor was chosen for this experiment, involving the use of a slightly enriched fuel, because of its high performances. The fuel is thus placed in severe operating conditions which exceed the needs of all research reactors.

It is these conditions, combined with the fact that the Osiris reactor had no margin of U-Al fuel, beyond the margins required for safety, which explain to a great extent the need for certain modifications in the core's primary circuit. We should recall that the reactor had been originally designed for operation at 50 MW; the power of 70 MW was not reached until 1968, after a slight modification of the pumps.

The reduction in the number of plates per element (17 instead of 24) therefore had to be compensated for by an increase in the primary flow and thus by a change in the pumps and their motors.

As the primary circuit had four groups of exchangers and pumps operating in parallel in the U-Al core, each pump was associated with an exchanger. Three of these units were used simultaneously.

Because of the impossibility of increasing the flow in each of the exchangers simultaneously with the change in the pumps, a modification in the principal circuit allowed the four exchangers to be supplied in parallel from each of the four pumps. A main collecter now connects the outlet of the pumps to the intake of the exchangers. Only three of the pumps are used at the same time; the fourth remains on standby. However, the flow goes into the four exchangers.

The other adaptations made for operation with the Caramel fuel were very minor and were limited to a few reinforcements of the dry fuel storage facility.

The modification of the DRG [Shield Rupture Detection System] had already been considered for the U-Al fuel. In the former situation, the DRG only gave an alarm signal and only used a detection system for delayed neutrons. The modification made consisted of introducing the DRG in the sequence of protective actions for the signal caused by delayed neutrons (action at 2/3) and adding a measurement of the gamma signal.

2.3. Experimental Studies

In addition to the irradiations and tests of the fuel, a major experimental program was used to support the core transformation:

a. A study of the core with the Isis reactor, starting in October 1978, a year before the fueling of Osiris;

b. A study of the hydraulic behavior, loss of load and vibrations, and of the fuel element in a test loop at Saclay;

c. A study of the thermal behavior of the duct at Grenoble.

2.3.1. Experimental Study of the Core

This study, done on the Isis, was designed to verify the data for the core, which are highly important for safety, and to determine the neutron flows and gamma heating in the places reserved for the experiments. This was essentially a complete qualification of the method of calculation used.

In the first phase, the program consisted of:

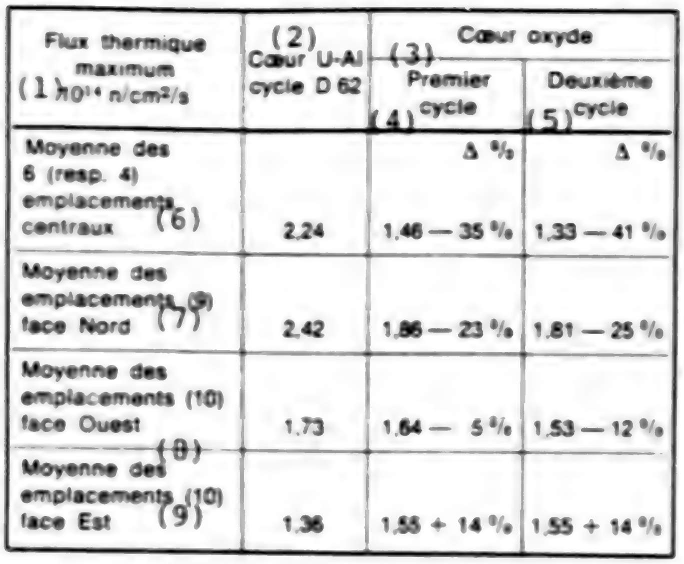
a. Making a subcritical approach by grad [illegible] fueling of the core, and determining the minimal critical size, then the available reactivity of the core which was to be operational in Osiris;

b. Measuring the efficiency of each of the six control rods;

c. Determining the distribution of power inside each of the fuel elements of the core in order to know, in every situation, the maximum power to be removed by a water duct.

To do this, the Isis core was identical to the first Osiris core. The flow measurements in the experimental sites which were not essential for the safety study of the core and for the compilation of the corresponding records were done in a later phase.

These measurements enabled us to verify some major parameters for irradiations: the fast and thermal neutron flows, and gamma heating.



(1) Flux thermique maximum 10^{14} n/cm^2/s	(2) Cœur U-Al cycle D 62	(3) Cœur oxyde	
		(4) Premier cycle	(5) Deuxième cycle
		Δ %	Δ %
Moyenne des 6 (resp. 4) emplacements centraux (6)	2,24	1,46 — 35 %	1,33 — 41 %
Moyenne des emplacements (9) face Nord (7)	2,42	1,86 — 23 %	1,81 — 25 %
Moyenne des emplacements (10) face Ouest (8)	1,73	1,64 — 5 %	1,53 — 12 %
Moyenne des emplacements (10) face Est (9)	1,36	1,55 + 14 %	1,55 + 14 %

Table 4: Results of Experimental Core Study

Key:

1. Maximum thermal flow
2. U-Al core: cycle D 62
3. Oxide core
4. First cycle
5. Second cycle
6. Average of six central locations
7. Average of locations on north side
8. Average of locations on western side
9. Average of locations on eastern side

These measurements confirmed the calculations, and gave us a precise estimate of the changes to be expected under test conditions. These data have also been confirmed by the experience acquired during the operation of Osiris.

A summary of the results is given in Table 4 (above).

Rapid Neutron Flow (E > 1 MVe)

The calculations had shown that the rapid flow was affected in an inverse ratio to the size of the core. This result was verified with Isis and with Osiris. In fact, we found that the average loss in rapid flow was a factor strictly and inversely proportional to the increase in the core size, when the number of elements was raised from 39 to 44, for hydraulic reasons peculiar to Osiris.

Thermal Neutron Flow

The very significant absorption of the new Caramel fuel, caused by its high uranium content, is expressed, for the same power, by a significant decline in thermal flow in the system (~40 percent for these experiments). However, the spectrum quality is better (approximately 40 percent gain in the rapid flow/thermal flow ratio).

The decline in thermal flow in the core has no unfavorable consequences for the experimental program, as the system is used solely for its rapid flow characteristics.

The thermal flow on the periphery is reduced on the average by 8 percent, but here we must also bear in mind the increase in the core size and the number of sites that can be used on the external grids.

γ Heating

γ heating decreases in the system, and this is an advantage for the experiments:

a.	U-Al core	10 to 15 W/g
b.	Caramel core	4 to 8 W/g

2.3.2. Thermo-Hydraulic Study

The measurements were designed to:

a. Determine the loss of load of the fuel element, bearing in mind the surface irregularities of the plate, caused by the special Caramel technology. This study was handled by the Reactor Service at Saclay, using the existing hydraulic loop for the tests of Osiris elements and irradiations;

b. And to ascertain the absence of vibrations in the standard fuel element and in the control element.

These measurements were made along with the determination of the loss of load in order to verify the lifting force of the elements and of the control rods (resulting from the upward circulation of the primary fluid in the reactor core).

A second series of tests conducted at Grenoble by the Department of Energy Transfer and Conversion concentrated on a thermal study of the duct. The results were analyzed jointly by the Department of Energy Transfer and Conversion and by the Reactor Study and Applied Mathematics Service.

All the results have shown that the Caramel element behaved much like the old U-Al element. The loss of load caused by friction is increased by about 5 percent but, considering this increase in the friction coefficient, the thermal behavior of the duct is slightly modified by the Caramel structure. The test results were analyzed under the code name of FLICA.

2.3.3. Safety Records

Because of the importance of the modifications, a detailed examination of their implications in terms of safety was conducted. In the very first phase, before the work, a complement to the Safety Report was issued and, after the fueling, a complete reedition of the Safety Report was released which covered, in addition to this safety study and the modifications made, the results of the start of service tests.

This reexamination of safety covered all the documents. However, the major studies and the most important modifications concerned the following areas:

a. Core physics: loading of the fuel, configuration, efficiency of the rods, power distribution, replacement of the fuel;

b. Primary cooling circuit of the core: new configuration of the circuit, pumps, exchangers, flows, loss of load, vibrations;

c. Thermohydraulics of the core at its permanent operational status, in transitional phases, and in natural convection;

d. monitoring of the first barrier: new DRG system; filtration circuit; automatic insulation of purification system;

e. Study of accidents and their radiological consequences on the environment.

III Behavior of the Fuel: Consequences for Operation

3.1. Record of Operation

The Osiris reactor was loaded with Caramel fuel in October 1979. The power increase test cycle took place in January/February 1980. Since then, and until July 1981, in addition to this test cycle, there have been 12 cycles of about 4 weeks each, operating at 70 MW, for a total of 21,600 MWj (see Table 5).

Cycles	Charge en uranium 235 en début de cycle (1) (g)	Energie fournie (2) (MWj)	Durée du cycle (3) en JEPP 70 MW	Irradiation moyenne des éléments sortis (4) (MWj/t U)
E 0	20 733	1 542	22	4 970
E 1	20 938	1 546	22,1	9 460
E 2	21 586	1 813	25,9	16 460
E 3	21 397	1 864	26,6	18 670
E 4	21 164	1 670	23,9	20 090
E 5	21 555	1 622	23,2	22 230
E 6	21 817	1 650	23,6	24 370
E 7	21 875	1 666	23.8	23 850
F 1	21 482	1 732	24,7	24 300
F 2	21 027	1 774	25,3	24 860
F 3	21 408	1 938	27,7	24 960
F 4	20 908	1 860	26,6	28 360
F 5	20 480	994	13,7	27 455

Table 5: Osiris Reactor: Cycle Characteristics.

Key:

1. Content of uranium 235 at start of cycle (g)
2. Energy supplied (MWj)
3. Duration of cycle in JEPP 70 MW
4. Average irradiation of elements removed (MWj/t U)

For each of these cycles, Table 5 gives the uranium 235 content at the start of the cycle, the energy supplied, the duration of the cycle, and the average irradiation of the elements removed. For the first core, the average enrichment had intentionally been reduced to about 6 percent, with fuels enriched to 4.75 percent, 5.62 percent, and 7 percent. The fuel now used is enriched to 7 percent. Towards the end of 1982, this enrichment will be increased to 7.5 percent.

Each element remains in the core for five to six cycles. During each cycle, there is a partial replacement of the fuel and a rearrangement of the remaining elements.

3.2. Conditions of Operation of the Fuel and Statistical Record

The conditions for the use of the fuel are quite stringent. In particular, the average and maximum specific powers are well beyond the values found for pressurized water reactors or for those possible for almost all the research reactors existing anywhere in the world:

a. Average specific power: 1,640 W/cm^3 of UO_2

b. Maximum specific power: 4,300 W/cm^3 of UO_2

In order to be certain of the good behavior of the fuel in the reactor, a program of systematic nondestructive examinations was undertaken. This entails monitoring the water ducts; this is done by a stress gauge and a comparison with the measurements made after manufacture. It covers all the assemblies unloaded after the first six cycles of operation and half of the assemblies removed after the next six cycles; this amounts to about 90 assemblies.

This program, which is now underway, will be completed by destructive examinations of one of the most heavily irradiated elements, having reached a mass combustion of 30,000 MWj/t U.

All the measurements done will help us to make an overall evaluation, statistically representative of the evolution of the characteristics and of the behavior of the Caramel Osiris fuel element under irradiation.

Since the start of service in Osiris, the average irradiation authorized has risen from 20,000 MWj/t U, the value designated as the first objective, to 25,000 MWj/t U in November 1980, and to 30,000 MWj/t U in February 1981. These authorizations are based on the good behavior of the fuel, the systematic nondestructive examinations made of the irradiated elements removed from the reactor, and destructive examinations of some elements. For the moment, the average irradiation level of 30,000 MWj/t U has not been reached in all of the elements removed. This level will be reached when the replacement elements are enriched to a level of 7.5 percent.

At present, 63 elements have exceeded 20,000 MWj/t U; of these, 26 are over 25,000 MWj/t U, and eight have reached an average irradiation level between 28,000 and 30,000 MWj/t U.

We should add that, for a fuel element whose average irradiation is close to 30,000 MWj/t U, the maximum irradiation is between 40,000 to 43,000 MWj/t U.

3.3. Behavior of the Fuel

The behavior of the fuel has been good and no major incident has caused any serious problems with contamination of the circuits. The only noteworthy incidents seem caused by problems arising from the manufacturing process used for the Caramel in this configuration and for the reactor's conditions of use.

During the power increase test cycle, three elements had to be removed even before the nominal power level was reached, because of abnormal rates in the DRG. Later, this sort of incident did not recur. An examination of one of the elements in hot cells at the Irradiated Fuels Research Laboratory at Saclay showed that this was caused by an initial manufacturing defect. After the first series of approximately 100 elements, the plate controls were improved and the satisfactory behavior of the fuel made it possible to increase the irradiation levels, as we indicated earlier.

Some bursts of γ activity in the DRG at the end of 1980 and in early 1981, which did not release iodes or disrupt the delayed neutron signal, were probably a sign of micro-leaks in some of the Caramel elements. Systematic examinations should enable us to determine the origin, either a shield defect or swelling.

3.4. Consequences for operation

As the few initial incidents mentioned above never caused any real circuit contamination problems, there have been no severe radiological consequences affecting the personnel. On the contrary, the individual dosimeter readings show a general decline in the doses received by the pperating personnel, in relation to the period when the highly enriched U-Al fuel was used. This is caused essentially by the replacement of the aluminum shield by a zircaloy shield, which has meant a very large decline in the ^{24}Na activity of the water in the primary circuits and capacitors.

The performance losses in neutron flows found in irradiations confirm the experimental studies on Isis and the preliminary calculations. The consequences are quite limited for the testing program. The reduction of the fast neutron flow by about 9 percent has no disadvantage other than lengthening the duration of irradiations. The notable loss in thermal neutron flow inside the core causes no problems, as the corresponding sites are used for rapid flow irradiations. Externally, the average 8 percent loss in thermal neutron flow is compensated by the adjusted position of the irradiations and the increase in the number of high-flow sites.

IV Conclusion

This demonstration of the use of a slightly enriched fuel in a high-performance research reactor is a technical experiment of interest from all points of view.

Generally speaking, it seems that a research reactor, even one with performances as high as those of Osiris, does not necessarily need a highly enriched fuel. Of course, this reduction in enrichment is accompanied by a certain modification in the characteristics of the core in terms of the neutron flows. These modifications have not significantly hindered most of the irradiations.

In the particular case of the oxide plate fuel, known as Caramel, its behavior is quite satisfactory. The few defects found have been minor and the reactor can be used with a completely normal regularity. The change, from a radiological point of view, has been of benefit for the personnel.

This demonstration experiment successfully conducted with Osiris gives France an alternative solution for the highly enriched fuel used in its multipurpose research reactors. It strengthens France's position for exporting research reactors, as international trade in highly enriched uranium may in the future be tightly restricted.

It is certain that, for most of the existing reactors and announced projects, the irradiation conditions for this fuel would be much less stringent than those that have been tested at Saclay for almost 2 years.

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